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Las Cruces, New Mexico 88003

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DISCRIMINABILITY OF SYMBOLS FOR TACTICAL INFORMATION DISPLAYS

Evelyn Williams and Warren H. Teichner

TECHNICAL REPORT 79-1

January 1979

Sponsored by AFOSR F44620-76-C-0013
Evelyn Williams, Principal Investigator

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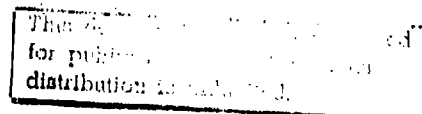
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DISCRIMINABILITY OF SYMBOLS FOR TACTICAL INFORMATION DISPLAYS

Evelyn Williams and Warren H. Teichner

New Mexico State University

One of the major human factors problems associated with complex display systems is the coding system by which information is conveyed to the human operator. The usefulness of the different informational codes depends upon a large variety of factors. Teichner (1977) suggested a series of principles specifying factors which determine the usefulness of a stimulus coding system. Included among those principles are the following: (1) The principle of attentivity refers to the attention-getting properties of the stimuli as a function of the amount and type of differences which exist between a stimulus item and the other stimuli in the display. The greater the relative attentivity of a stimulus, the more quickly it will be detected. (2) The principle of identifiable code elements pertains to the number of elements in the code which can be specified by name. The more specifically nameable elements in the code, the more useful it is for absolute identification. (3) The principle of information states that the speed of response is directly proportional to the amount of stimulus information. Stimulus information, in turn, depends upon the number of stimulus events which might be displayed and the probability of each. (4) The principle of input rate suggests that the rate at which information can be handled in a limited time frame is dependent upon the number of critical features in the stimulus, the number of simultaneous stimuli, the amount of information, and the time between successive stimuli. (5 & 6) The principles of chunking and information reduction indicate that some coding systems may be grouped together for storage in memory more easily than other coding systems. The coding systems more amiable to this grouping may decrease

or increase processing time depending upon whether or not recoding is necessary and the number of steps it takes to recode the information from the chunked version back to the individual stimulus codes. (7) The principle of multiple coding refers to situations in which the coding of the information makes use of more than one dimension in the stimulus (e.g., a red square). The effect of such multiple coding is dependent upon the integrality of the stimuli and the level of stimulus redundancy. (8) The principle of processing priority indicates that some codes may be processed prior to other simultaneously displayed codes due to previous experience, placement in the visual field, etc. (9) The principle of stimulus coding compatibility refers to the fact that for a stimulus code to result in the fastest possible processing, they must be coded in a manner which is compatible with the response code. (10) The principle of working memory points out the need to have a stimulus code which may be remembered. If the code is difficult to retain it will be difficult for the operator to use.

While all of Teichner's principles represent important factors to be considered in display design, probably the most elementary is the principle of attentivity which includes factors related to the discriminability or confusability of the stimulus items. The operator must be able to discriminate the stimulus elements from one another or his responses to the display become meaningless. If the individual stimulus coding elements do not serve as distinct entities, the remaining coding principles have little effect. It makes little difference if the display elements are easily grouped or have stimulus response compatibility if the operator must make a response based on absolute identification but cannot distinguish which stimulus element was presented. This is not to say that the presentation of highly confusable stimuli is always damaging to performance. Confusability of various stimulus elements would be

beneficial if the operator is required to make a classification response in which the elements which are confusable with one another are placed in the same category. Given that the application of other principles for designing displays is dependent upon discriminability, a necessary first step in the development of a coding system is the specification of the discriminability of the stimulus elements from one another.

In the visual realm, stimulus information may be coded in a variety of ways. It may be coded as colors, locations, shapes, alphanumerics, etc. The dimension for coding visual information which probably has the most flexibility in terms of allowing for the greatest variety of nameable display symbols is that of shape. The present study was directed toward the measurement of the attensity factors of discriminability and confusability of 210 symbol codes which varied along the shape dimension. Attensity variations in visual stimuli may be specified by examining operators' responses to these stimuli in choice reaction time or search tasks. The accuracy of response and response latency both provide valuable information as to the confusability and ease of identifying the stimulus elements. Therefore, the 210 black and white drawings were compared with one another in a visual search task in which the operator was to respond to each of the stimuli indicating whether or not the stimulus was an example of the symbol previously specified as the target item.

Method

Subjects

The subjects for the study were student volunteers from the New Mexico State University campus. There were six subjects, three male and three female, all right-handed. The subjects were paid \$2.00 per hour for their participation.

Stimuli and Apparatus

The stimuli were 210 symbols, see Figure 1, recommended by the Symbol Standardization Committee of the Joint Tactical Information Distribution System (JTIDS). The symbols were selected on the basis of being frequently recommended by tactical pilots in structured interviews.

The individual symbols were drawn in white ink on a black background. They were drawn so that when displayed to the subject, the line widths and dot widths subtended 1.0 minute of visual angle. The stimuli were drawn on a 1.5 cm square black surface which was mounted on a 4 cm square black cardboard backing.

The stimuli were presented to the subjects on a 5 ft. x 5 ft. (1.52 m x 1.52 m) board in a 15 x 15 matrix. The separation between the stimulus items was 9.53 cm center-to-center in both the horizontal and the vertical direction. This separation resulted in a visual angle of 3.251° between each stimulus item. There were a total of 45 stimulus display boards, 3 display boards were used for practice and the remaining 42 display boards were used for the experimental trials. For each display board, the first row of the matrix contained 15 symbols which served as targets, a different one of these symbols was specified as the target for each of 15 trial blocks. In Rows 2 through 15 of the matrix, there were 210 symbols which served as the stimulus field. The stimulus field contained one example of each of the 195 symbols which were not used as a target on the display board. In addition, 5 of the target symbols occurred once, 5 target symbols occurred twice, and the remaining 5 target symbols were absent. Centered beneath each symbol in the display was a red LED of .51 cm in diameter. Each LED had a luminance of 1.5 milliamber (4.77 cd/m^2). The display was situated in a dimly lit room and received illumination from four incandescent lamps. One lamp was located at each of the four sides of the board and produced an overall illumination of 64 footcandles (688.89 lx) on the surface of the board.

The subject was seated at a desk with his head held stationary by means of a head and chin rest. A two-button response panel was located on the right-hand side of the chin rest. The left button was labeled "no" while the right button was labeled "yes." The display board was placed directly in front of the subject. The bottom of the display was elevated 30.48 cm from the ground and the display was located 167.64 cm from the subject's eyes.

The sequencing of the LED under the symbols on the display board was accomplished by an internal counter which was controlled by the subject's responses. When the subject responded to a symbol the lighting of the LEDs on the display board advanced to the LED under the next symbol on the display board. The subject's yes and no responses and their associated response times were obtained by means of an internal crystal clock and counter. The clock began timing when the LED under a symbol was lit and the timer stopped and reset when the subject made a response. The subject's response and response time were stored and fed to a printer every third trial.

Procedure

Prior to their first experimental session, subjects received orientation instructions which emphasized the importance of their participation and which indicated that the data obtained would be used for the design of an information display system. At the beginning of the experimental sessions, subjects were instructed in the task. Subjects were told that the top row of symbols were the targets. For the first trial block (i.e., one entire run through the display board) the first symbol in the first row was to serve as the target. For the second trial block, the second symbol was the target. This procedure continued for 15 trial blocks until all 15 target items were used.

Subjects were told to inspect the target item for whatever amount of time they felt necessary to become familiar with the target. Holding the target in

memory they were told to scan the display, symbol-by-symbol, in order to identify targets and non-targets. Subjects began with the first symbol in the display field and made a push button response to each stimulus in the field. Red LEDs located beneath the symbols indicated to which symbol the subject was to make a response. If the symbol was not the target, they were to respond by pushing the no button with the index finger of their right hand. The pressing of the response key resulted in the recording of the response time and caused the red light to extinguish under the symbol and to light up under the subsequent symbol.

Subjects were presented with two display boards per day, or a total of 30 trial blocks. Each display board was presented to the subject twice with the presentations being separated by one or two days. This resulted in three practice display sessions, or a total of 45 practice trial blocks, and 1260 experimental trial blocks with each of the 210 symbols serving as the target six times. Subjects participated in the experiment five days per week for approximately eight and one half weeks.

Results and Discussion

Each of the 210 symbols served as target items on six blocks of trials. Over these six trial blocks, six different reaction times were obtained to each of the 209 non-target items and to the one target item. These reaction times were averaged over the six trial blocks and the six subjects to obtain average reaction times for the 210 symbols in each of the 210 different target conditions. The reaction time data for each target condition was examined in terms of the reaction time to the target item itself and the mean, median, and standard deviation of the reaction time to the non-target items.

Separate analyses of variance were conducted over the mean reaction times to the target and non-target items to determine if there were any practice effects beyond that allowed for by giving the subjects the 45 practice trial blocks. This analysis indicated that there were no significant practice effects on response times either for the target, $F(1, 14) = .364, p > .05$, or non-target items, $F(1, 14) = .611, p > .05$. The mean response time to target items occurring in the first 90 trial blocks was 535.49 msec. as compared to a mean of 545.76 msec. for target items occurring in the last 90 trial blocks. For non-target items, the mean response time over the first 90 trial blocks was 354.40 msec. while the mean over the last 90 trial blocks was 349.99 msec.

The subjects' responses were further examined to determine if there were any differences in response time on trial blocks in which no targets were present as compared to trial blocks in which two target items were present. A random sample of five targets were chosen to look at the effects of target absence as compared to the presence of two target items. The mean response time for the target absent trial blocks was 317.13 msec. while the mean response time with two targets present was 317.54 msec. As indicated, the presence or absence of the target has no noticeable effect upon non-target response time.

The average reaction time to the symbols are presented in Table 1. As can be seen, the response time to the symbols when they served as target items tended to be longer than the average response time to the non-target items. This difference in response time may have been partially due to a response bias towards a negative response. Since subjects received at the most two target items per display board containing 210 items, the probability of a negative response was significantly higher than the probability of a positive response. This may have led subjects to adopt a strategy of initially assuming a negative or non-target response. Given this strategy, the correct

identification of a target items would require a blocking of this initial response and a verification of the stimulus information by comparing the distal stimulus with an internal representation of the target item. It would be anticipated that this difference in response time to target and non-target items would be reversed if the response probabilities were reversed. Research indicates that stimulus presentation probability is directly related to response time particularly for responses which are not maximumly compatible with the stimulus (Theios, 1975). It is therefore anticipated that target and non-target identification would be directly related to their relative probabilities.

There was a great deal of difference in the average reaction time to the different symbols when they served as targets. The shortest response time was the 305-msec response to Target 41 while the longest time of 1307.67 msec was to Target 34. These differences in reaction time may be taken to indicate differences in the discriminability of the symbols. Those symbols which were most easily differentiated from the non-target symbols should require the shortest amount of response time while greater amounts of time should be required for those symbols which were more difficult to discriminate. Based on this conceptualization, a rank ordering of the discriminability of the 210 symbols was made based on the reaction time to these symbols when they served as target items. This rank ordering is presented in column 2 of Table 2. In the event of ties among symbols, the tied symbols were given the average of the rankings of the tied items. Based on this ranking, the ten most easily discriminated symbols in order were: 41, 85, 169, 53, 28, 185, 51, 71, 91, and 190. The ten most difficult to discriminate items were: 34, 37, 97, 45, 111, 200, 194, 172, 141, and 159 in order from most difficult to least difficult.

It might be assumed that the greater the amount of time required to respond to the non-target items in the presence of different target items, the more

difficult the discrimination. Based on this assumption, the mean, median, and standard deviation of the reaction time to the non-target items were determined for each target condition. These statistics for each target condition are presented in Table 1. As can be seen, the response times to the 209 symbols serving as non-target items varied between target conditions. Under some target conditions, e.g., Target 70 with a non-target mean reaction time of 425.91 msec., it takes noticeably longer to reject the non-target items than under other target conditions, e.g., Target 95 with a mean non-target reaction time of 286.05 msec. As indicated previously, this difference in non-target response time is unrelated to the amount of practice in target and non-target identification. These data suggest that the amount of time it takes to reject nonrelevant information in a display is dependent upon the particular information for which the display is being scanned. This difference in non-target response time is not as substantial as that between different target items. However, it would tend to effect the amount of time required to scan an entire stimulus display and to make a response on the basis of a single target symbol. The symbols were, therefore, rank ordered in relation to the mean reaction time to the non-target items. This rank ordering is presented in Column 3 of Table 2. As indicated before, in the event of ties, the average ranking of the tied items was used.

Non-target response time was also found to vary from symbol-to-symbol within a given target condition. This variability is indicated by the standard deviation which is presented in Column 5 of Table 1. For some target conditions the standard deviation of the non-target response times was small (e.g., Targets 13, 21, 57, etc.) and for other target conditions the standard deviation was relatively large (e.g., 26, 34, 200, etc). The small standard deviation indicates a relatively consistent response time and degree of confusion of all the

non-targets with the target in that condition. The larger standard deviation typically indicates that some non-target items are highly confusable with the target and require more time for the operator to discriminate them from the target. In these target conditions, most of the other non-target symbols were relatively consistent in their response time or confusability with the target. This higher confusability of a few non-target items is reflected in a larger mean than median reaction time in those conditions which have larger standard deviations, see Table 1. Further evidence as to the source of non-target response variability comes from an examination of the individual non-target response times in conjunction with confusion errors. This examination indicated that the longest response times to non-target symbols were associated with those symbols, which based on the number of confusion errors, were highly confusable with the target. For example, when Symbol number 119 was the target, subjects confused Symbol 208 with the target on over half of the trials. While the mean non-target response time in this condition was 360 msec., the average time to Symbol 208 was 930 msec.

The variability in the response time to the non-target items produces a large mean non-target response time resulting from only a few non-target items. If these highly confusable items were eliminated from use in the display, the rank orderings of the symbols based on the mean non-target response times would provide an inaccurate view of the confusability of the symbols. Rank orderings of the targets in terms of the standard deviation and median response time are presented in Table 2 with the ranking going from lowest to highest. Ties in the rank orderings of the symbols were handled by using the average rankings of the tied items. The symbols which rank at the bottom of the list in terms of standard deviation, would be those symbols which would be highly confusable with one or more of the other symbols in the stimulus set. If symbols which

were highly confusable with the target were dropped from the stimulus set, the ranking of the stimuli, based on the medians would provide a more accurate view of the relative discriminability of the stimuli than the ranking based on the mean non-target response time. The median, rather than the mean response times of the non-target items should therefore be used as the basis for ranking the discriminability of the symbols if highly confusable symbols are eliminated.

Presented in Table 3 are the average number of misses, confusion errors, and a listing of the non-target symbols which were confused with the target and, in parentheses, the total number of times each symbol was confused. A maximum mean of six misses of the target symbol were possible while each non-target symbol could have a maximum total of 36 confusions with the target. In general, the confusion errors were not one-sided. That is, if Symbol X was misidentified as target Symbol Y, then Symbol Y tended to be misidentified as Symbol X when it was the target. The inclusion of highly confusable stimuli in the stimulus set for a display could lead to serious errors if the response to the displayed items is identification. As indicated before, if the items are to be classified rather than identified, it might be expected that high confusability among items of the same class would increase response speed.

For the purposes of this report, it was assumed that the operator's task is the identification of the individual symbols. Using this orientation, an examination of the confusability errors among the symbols indicates that performance may be improved by the elimination of certain symbols. Those symbols recommended for elimination from the stimulus set are presented in Table 4 along with a listing of those stimuli with which they are highly confusable and whose identification would be aided by this elimination. These stimuli are listed in order of the importance of their elimination based on the number of times they were confused with other symbols and the other symbols were confused with them.

While the elimination of these symbols from the stimulus set will not eliminate all confusion errors, the remaining confusion errors are minimal and represent no detriment to the discriminability of the stimulus set.

With the highly confusable stimuli eliminated from the stimulus set, the symbols may be ranked in terms of their discriminability based upon the response time to the non-target symbols. A ranking of the symbols based on the target mean, non-target median, and a combination of these response times, is presented in Table 5. This new ranking should give some indication of the relative discriminability of the 192 symbols left in the stimulus set after the confusable symbols have been eliminated. The new ranking should not be considered to be completely accurate as the removal of the confusable stimuli may affect both target and non-target identification times. In order to have a more accurate ranking of the symbols, it is recommended that further discriminability research be conducted with the revised set of symbols.

In conclusion, in order to design the most efficient information display it is important to consider a number of variables related to the type of task and the interrelationship of stimulus, response and task variables. In an identification task it is necessary to determine the relative discriminability of stimulus items before more advanced principles of display design can be applied. The relative discriminability of 210 stimulus items was determined by a comparison of response times and errors in a search task in which the operator was attempting to identify symbols as being examples or non-examples of a prespecified target item. The characteristics of the target item relative to non-target items determined the response times to target and non-target items and the variability among responses to non-target items. Highly confusable stimuli tended to increase response time and variance.

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Table 1

Mean Target Reaction Time and Mean, Median, and Standard
Deviation of the Non-Target Reaction Times in Milliseconds

Target Number	Reaction Time to Target	Non-Target		
		Mean	Median	Standard Deviation
1	606.81	371.62	366.39	23.66
2	489.30	315.24	309.83	25.94
3	579.77	323.21	321.11	12.47
4	529.53	304.87	301.11	15.08
5	622.16	320.82	316.50	25.74
6	575.33	329.23	324.53	27.33
7	576.47	305.59	303.61	11.07
8	510.11	377.10	374.41	13.62
9	627.14	393.46	382.27	57.60
10	542.22	362.15	354.89	41.99
11	560.67	365.63	362.61	16.85
12	719.92	348.33	341.25	26.82
13	498.27	316.81	315.13	10.92
14	606.97	325.25	320.89	23.42
15	607.55	418.36	416.25	12.87
16	475.56	307.00	303.47	12.43
17	620.11	339.43	331.88	35.52
18	692.22	326.29	320.00	48.80
19	711.89	343.33	336.17	30.70
20	713.64	516.30	326.47	39.72
21	603.94	319.75	317.66	11.89
22	607.08	370.63	362.08	39.94
23	501.75	323.07	320.22	15.36
24	529.11	339.24	334.31	16.40
25	406.53	307.17	300.53	28.26
26	657.80	368.66	362.44	32.73
27	520.25	373.15	367.97	34.41
28	352.17	349.78	341.72	42.66
29	657.33	308.16	302.72	22.57
30	482.06	308.02	303.92	18.27
31	441.97	311.94	304.44	30.47
32	554.52	327.05	321.86	36.36
33	666.33	346.08	337.31	37.63
34	1307.67	390.25	371.03	86.43
35	489.05	304.24	301.61	14.68
36	608.55	327.37	321.41	32.55
37	950.28	360.95	349.03	52.16
38	679.05	325.79	320.66	22.77
39	547.81	381.95	367.39	65.89
40	636.58	325.19	323.02	12.48

Table 1 Continued

Target Number	Reaction Time to Target	Non-Target		
		Mean	Median	Standard Deviation
41	305.00	326.78	323.16	24.85
42	610.61	326.03	314.63	41.73
43	540.03	363.41	354.81	46.25
44	722.63	323.12	319.30	21.37
45	845.22	338.35	331.31	23.89
46	556.56	325.92	323.27	13.08
47	615.81	352.81	348.72	16.26
48	535.78	312.25	309.08	13.21
49	602.14	331.80	328.97	14.03
50	610.58	359.03	356.05	14.29
51	395.52	295.60	292.16	15.66
52	635.83	311.87	309.19	12.71
53	330.91	320.44	316.66	20.99
54	458.27	309.08	302.42	25.16
55	488.44	420.24	417.36	21.04
56	493.17	304.32	301.72	12.66
57	593.83	330.40	328.94	9.73
58	586.22	385.34	381.91	16.15
59	664.42	393.21	386.05	30.64
60	471.94	311.14	306.14	19.84
61	680.44	344.44	341.42	13.19
62	547.33	334.21	332.08	12.61
63	484.67	314.58	328.61	11.68
64	472.39	358.84	356.58	12.32
65	520.22	315.08	310.58	20.29
66	488.69	360.54	358.11	12.73
67	596.36	323.59	321.27	10.99
68	489.61	302.18	300.30	12.95
69	463.11	323.00	320.11	13.08
70	528.25	425.91	424.22	12.07
71	400.18	313.52	308.33	23.60
72	543.06	323.27	318.53	19.68
73	624.39	360.88	358.89	13.76
74	582.64	359.82	355.75	17.11
75	466.42	366.85	364.36	12.89
76	558.36	328.24	326.28	9.24
77	470.39	323.47	321.19	12.48
78	522.14	305.34	300.47	19.43
79	523.42	310.50	306.53	13.61
80	534.08	414.34	412.97	9.85
81	549.44	360.78	357.58	14.26

Table 1 Continued

Target Number	Reaction Time to Target	Non-Target		
		Mean	Median	Standard Deviation
82	505.17	367.53	360.83	31.55
83	597.39	354.76	351.22	14.66
84	689.44	387.87	383.00	19.83
85	308.38	305.21	302.02	29.88
86	437.47	325.46	324.08	9.39
87	472.11	325.40	324.00	8.64
88	542.17	328.19	325.86	10.13
89	446.19	322.45	319.39	16.68
90	501.02	309.13	305.67	14.40
91	402.67	290.06	286.01	14.47
92	577.47	322.63	322.06	8.41
93	517.36	322.84	321.81	10.51
94	503.06	413.83	410.75	12.64
95	444.47	286.05	303.97	16.21
96	521.77	311.11	309.05	10.08
97	878.17	317.03	308.44	66.36
98	581.08	381.98	378.56	15.28
99	625.42	332.08	329.64	12.22
100	530.67	418.12	415.61	14.21
101	602.75	357.56	353.94	15.63
102	528.44	330.99	326.97	13.74
103	499.33	359.09	357.25	11.14
104	537.39	304.52	302.50	11.13
105	509.25	418.65	416.00	19.40
106	579.72	314.44	311.00	21.09
107	661.17	316.86	313.70	11.17
108	622.61	368.76	362.19	28.21
109	558.89	358.47	354.58	17.99
110	458.02	296.96	292.63	20.04
111	809.05	310.23	306.47	33.80
112	685.89	425.10	413.44	44.90
113	557.17	335.72	332.42	16.21
114	476.00	299.16	297.30	11.09
115	560.56	378.63	375.94	15.21
116	539.22	302.79	298.80	17.71
117	541.19	323.76	321.97	10.22
118	504.33	320.08	318.13	9.97
119	554.63	313.37	310.97	9.54
120	504.75	317.65	316.69	9.90
121	554.14	413.65	412.27	11.23
122	492.00	284.05	303.63	15.29
123	459.38	316.48	314.50	10.46
124	587.00	383.32	376.50	46.01

Table 1 Continued

Target Number	Reaction Time to Target	Non-Target		
		Mean	Median	Standard Deviation
125	589.14	336.74	333.31	16.23
126	519.47	306.98	304.33	13.81
127	548.64	379.50	377.00	13.06
128	549.50	313.78	310.72	12.44
129	719.39	361.21	352.53	39.37
130	710.36	323.77	322.00	10.01
131	557.36	320.77	319.06	10.44
132	447.61	304.75	302.05	13.28
133	517.75	302.22	297.05	17.10
134	539.62	311.45	310.22	10.38
135	559.05	326.28	322.89	12.14
136	478.44	329.13	327.17	11.31
137	530.06	370.69	368.31	13.25
138	459.91	318.57	313.69	17.82
139	575.97	370.76	366.80	16.96
140	576.67	336.86	331.36	48.00
141	762.08	321.43	318.19	14.39
142	557.44	372.91	368.75	21.02
143	613.19	358.47	354.72	22.65
144	541.86	378.30	374.58	25.94
145	520.61	416.13	412.89	18.05
146	531.05	306.98	302.38	19.27
147	589.72	359.50	356.86	16.39
148	528.00	313.62	308.69	23.45
149	509.11	301.20	298.25	13.79
150	495.00	324.82	321.14	18.04
151	498.52	308.41	305.27	13.20
152	557.25	323.98	320.89	14.00
153	668.94	325.39	321.42	20.57
154	532.63	323.48	320.38	14.32
155	650.64	315.51	312.78	21.27
156	543.70	315.77	312.81	16.64
157	614.00	338.18	334.58	30.06
158	623.05	303.02	301.14	12.46
159	750.33	353.42	347.44	30.67
160	541.69	416.04	414.00	15.95
161	578.86	315.49	313.05	14.79
162	507.38	319.25	316.61	21.29
163	575.80	304.09	300.61	15.44
164	678.30	318.79	314.89	26.89
165	512.92	332.46	329.67	21.19
166	614.00	379.40	374.44	30.33
167	455.14	359.56	353.97	31.51

Table 1 Continued

Target Number	Reaction Time to Target	Non-Target		
		Mean	Median	Standard Deviation
168	513.69	412.50	409.17	15.51
169	316.33	318.25	314.80	22.14
170	507.22	301.89	299.14	16.73
171	508.39	310.57	308.39	14.67
172	771.67	325.00	322.11	10.56
173	531.19	310.89	309.41	10.06
174	613.36	360.70	355.41	25.71
175	475.67	304.60	300.19	20.52
176	496.78	356.52	353.83	16.45
177	487.92	357.98	354.25	23.65
178	447.83	300.50	297.17	14.52
179	492.56	383.95	380.33	19.36
180	598.47	365.28	358.97	34.68
181	627.19	330.46	326.61	45.77
182	465.83	318.73	314.89	17.31
183	435.67	318.04	314.17	17.46
184	527.36	329.60	325.31	15.15
185	355.81	355.71	351.97	16.06
186	576.58	357.04	356.50	11.25
187	654.17	316.80	313.78	13.54
188	600.47	322.19	318.95	23.88
189	512.00	415.81	414.66	10.41
190	405.92	363.30	358.50	45.41
191	570.78	418.48	416.39	20.66
192	593.58	316.46	312.58	24.44
193	577.17	334.94	330.08	40.77
194	781.22	350.97	343.78	67.38
195	473.00	362.55	358.64	27.29
196	508.86	311.88	307.36	15.96
197	605.83	309.55	304.08	42.87
198	530.88	306.94	304.69	14.71
199	693.58	360.45	353.33	43.45
200	804.37	325.94	318.70	40.52
201	555.44	362.57	356.61	30.99
202	502.69	375.30	370.44	27.35
203	553.39	415.86	412.94	18.49
204	514.36	359.16	356.08	15.10
205	566.22	316.50	314.27	14.23
206	669.29	326.59	318.70	46.63
207	558.30	307.61	304.02	17.94
208	658.58	332.18	327.67	29.48
209	508.58	374.90	371.25	19.85
210	461.47	353.76	349.38	38.66

Table 2

Rank Order of Targets in Terms of Mean Reaction Time to the Target,
Mean, Standard Deviation, and Median Reaction Times to Non-Target Items

Target Number	Reaction Time to Target	Non-Target		
		Mean	Standard Deviation	Median
1	157	177	150	175
2	43	53	158	49
3	140	84	40	91
4	87	18	83	15
5	169	75	157	70
6	130	112	163	109
7	133	21	23	126
8	67	182	62	184
9	174	195	206	193
10	104	163	192	153
11	127	169	107	173
12	199	135	160	134
13	50	61	21	69
14	158	95	146	89
15	160	205	49	207
16	33	25	37	25
17	168	131	183	126
18	193	104	205	84
19	196	132	174	132
20	197	123	188	113
21	155	71	32	74
22	159	174	189	170
23	54	82	88	86
24	86	130	103	130
25	11	26	166	13
26	181	172	179	172
27	77	179	181	178
28	5	136	194	137
29	180	31	143	24
30	37	30	119	28
31	14	45	171	33
32	114	107	184	98
33	185	134	185	134
34	210	193	210	182
35	42	13	79	17
36	161	108	178	95
37	209	161	193	141
38	189	99	145	88
39	108	187	207	177
40	177	94	41	104

Table 2 Continued

Target Number	Reaction Time to Target	Non-Target		
		Mean	Standard Deviation	Median
41	1	106	154	105
42	162	102	195	65
43	99	167	202	152
44	200	83	141	82
45	207	129	152	125
46	117	100	53	106
47	167	138	101	140
48	95	46	57	46
49	153	118	66	121
50	68	150	71	157
51	7	2	92	2
52	176	43	46	47
53	4	73	134	72
54	21	33	155	22
55	40	208	136	209
56	47	14	45	18
57	148	114	6	120
58	143	191	97	192
59	184	194	172	195
60	29	41	127	37
61	190	133	55	136
62	107	122	43	128
63	38	117	31	119
64	31	149	36	156
65	76	52	130	51
66	41	157	47	164
67	149	88	22	94
68	44	8	51	11
69	25	81	54	85
70	84	210	33	210
71	8	48	148	41
72	105	85	125	77
73	172	160	48	167
74	142	155	110	155
75	27	170	50	174
76	123	110	3	113
77	28	86	42	93
78	80	20	124	12
79	81	37	61	39
80	94	199	7	201
81	110	159	70	163

Table 2 Continued

Target Number	Reaction Time to Target	Non-Target		
		Mean	Standard Deviation	Median
82	59	171	177	169
83	150	141	77	143
84	192	192	126	194
85	2	19	168	19
86	13	97	4	108
87	30	98	2	107
88	103	109	13	112
89	16	78	106	83
90	53	34	74	36
91	9	1	75	1
92	137	79	1	101
93	73	80	19	97
94	56	198	44	197
95	15	29	99	29
96	79	40	12	45
97	208	63	208	43
98	141	188	86	190
99	173	119	35	122
100	89	204	68	205
101	154	145	91	147
102	85	116	63	116
103	52	151	26	162
104	96	15	25	23
105	66	207	123	206
106	139	51	137	54
107	183	62	27	60
108	170	173	165	171
109	124	147	116	150
110	20	3	129	3
111	206	36	180	38
112	191	209	198	202
113	118	125	98	129
114	35	4	24	6
115	126	183	85	187
116	97	10	113	8
117	100	89	14	99
118	57	72	9	75
119	115	47	5	53
120	58	64	8	73
121	113	197	28	198
122	45	27	87	27
123	22	58	18	64
124	144	189	201	188

Table 2 Continued

Target Number	Reaction Time to Target	Non-Target		
		Mean	Standard Deviation	Median
125	145	126	100	130
126	75	23	65	32
127	109	186	52	189
128	111	50	38	52
129	198	162	187	111
130	195	90	10	100
131	120	74	17	81
132	17	17	59	20
133	74	9	109	4
134	98	42	15	50
135	125	103	34	103
136	36	111	30	117
137	88	175	58	179
138	23	67	114	59
139	132	176	108	176
140	135	127	204	126
141	202	76	73	76
142	121	178	135	180
143	163	148	144	151
144	102	184	159	186
145	78	203	118	199
146	91	24	121	21
147	146	153	102	161
148	83	49	147	44
149	65	6	64	7
150	48	92	117	92
151	51	32	56	35
152	119	91	82	89
153	186	96	132	96
154	93	87	72	87
155	178	55	139	56
156	106	56	105	57
157	165	128	169	132
158	171	11	39	16
159	201	139	173	139
160	101	202	94	203
161	138	54	81	58
162	61	70	140	71
163	131	12	89	14
164	188	69	161	67
165	70	121	138	123
166	166	185	170	185
167	19	154	176	148

Table 2 Continued

Target Number	Reaction Time to Target	Non-Target		
		Mean	Standard Deviation	Median
168	71	196	90	196
169	3	66	142	66
170	60	7	93	9
171	62	38	78	42
172	203	93	20	102
173	92	39	11	48
174	164	158	156	154
175	34	16	131	10
176	49	143	104	146
177	39	146	149	149
178	18	5	76	5
179	46	190	122	191
180	151	168	182	168
181	175	115	200	115
182	26	68	111	67
183	12	65	112	62
184	82	113	84	110
185	6	142	96	144
186	134	144	29	159
187	179	60	60	61
188	152	77	151	80
189	69	200	16	204
190	10	166	199	165
191	129	206	133	208
192	147	57	153	55
193	136	124	191	124
194	204	137	209	138
195	32	164	162	166
196	64	44	95	40
197	156	35	196	31
198	90	22	80	34
199	194	156	197	145
200	205	101	190	73
201	116	165	175	160
202	55	181	164	181
203	112	201	120	200
204	72	152	67	158
205	128	59	69	63
206	187	105	203	78
207	122	28	115	30
208	182	120	167	118
209	63	180	128	183
210	24	140	186	142

Table 3

Average Number of Misses and Confusion Errors and
a List of the Symbols Confused with the Target and the
Total Number of Times they Were Confused in Parentheses

Target Number	Number of Misses	Number of Confusions	Non-Targets Confused With the Target Item
1	2.00	-	-
2	1.16	.66	129(2), 31(1), 9(1)
3	1.16	.50	4(1), 149(1), 205(1)
4	1.16	.16	104(1)
5	1.33	.66	14(4)
6	.66	.16	26(1)
7	1.16	.16	4(1)
8	2.00	.50	91(1), 93(1), 202(1)
9	2.00	.83	129(3), 12(1), 2(1)
10	.50	-	-
11	1.16	-	-
12	.50	-	-
13	1.00	.16	7(1)
14	.83	.33	5(2)
15	.83	.16	11(1)
16	1.00	.16	89(1)
17	.66	.50	31(2), 52(1)
18	1.66	1.83	27(10), 46(1)
19	1.33	.33	24(1), 37(1)
20	.83	.66	34(4)
21	.66	.83	23(4), 132(1)
22	1.16	.33	29(1), 189(1)
23	.66	.16	207(1)
24	2.50	-	-
25	1.16	.50	173(1), 185(1), 187(1)
26	.83	1.50	6(8), 196(1)
27	1.83	2.66	18(16)
28	1.00	.16	37(1)
29	1.16	-	-
30	1.50	.50	72(2), 198(1)
31	.83	.50	17(3)
32	.50	.66	23(3), 164(1)
33	1.00	.83	39(5)
34	2.50	2.16	20(7), 42(3), 19(1), 33(1), 169(1)
35	1.16	.33	90(1), 104(1)
36	.66	-	-
37	.66	-	-
38	1.33	.16	134(1)
39	2.66	3.00	33(7), 42(5), 37(3), 3(1)
40	.50	-	-
41	.16	-	-

Table 3 Continued

Target Number	Number of Misses	Number of Confusions	Non-Targets Confused With the Target Item
42	1.83	2.00	34(3), 39(1), 33(1), 12(1), 25(1), 1(1), 23(1), 15(1), 19(1), 24(1)
43	1.83	-	-
44	.83	-	-
45	.66	-	-
46	.66	.16	96(1)
47	1.16	-	-
48	1.66	1.33	126(5), 138(2), 127(1)
49	1.33	.33	14(1), 41(1)
50	1.33	.50	33(1), 73(1), 167(1)
51	1.33	.83	14(1), 110(1), 131(1), 175(1), 182(1)
52	.50	-	-
53	1.50	.33	52(1), 210(1)
54	1.00	-	-
55	2.66	-	-
56	1.16	.50	35(1), 116(1), 179(1)
57	1.00	-	-
58	.50	-	-
59	2.66	.16	79(1)
60	1.83	.66	2(1), 89(1), 91(1), 142(1)
61	.50	-	-
62	.66	-	-
63	2.00	-	-
64	.66	.33	16(1), 72(1)
65	.66	.16	167(1)
66	.66	-	-
67	1.50	.16	153(1)
68	1.16	.33	30(1), 170(1)
69	1.83	.50	32(2), 80(1), 119(1)
70	1.33	-	-
71	.83	.66	19(1), 23(1), 26(1), 27(1)
72	1.83	.83	29(1), 30(1), 74(1), 79(1), 80(1)
73	1.16	-	-
74	1.16	-	-
75	.66	-	-
76	.83	-	-
77	.83	.33	93(2)
78	.83	-	-
79	1.83	.16	67(1)
80	1.50	-	-
81	1.16	-	-
82	.83	-	-
83	.83	-	-

Table 3 Continued

Target Number	Number of Misses	Number of Confusions	Non-Targets Confused With the Target Item
84	.33	-	-
85	.33	.33	156(2)
86	1.66	-	-
87	.16	-	-
88	.66	.16	186(1)
89	.83	.16	174(1)
90	.16	.16	9(1)
91	1.33	.50	16(1), 36(1), 60(1)
92	-	-	-
93	1.00	.16	58(1)
94	.16	-	-
95	.50	-	-
96	-	.16	23(1)
97	1.50	3.33	111(18), 112(2)
98	1.00	-	-
99	.16	-	-
100	1.50	-	-
101	.50	-	-
102	1.83	.16	81(1)
103	1.16	-	-
104	1.83	-	-
105	-	-	-
106	.83	.16	108(1)
107	.33	-	-
108	2.53	.16	49(1)
109	1.33	.16	101(1)
110	.83	.16	188(1)
111	.66	.16	23(1)
112	.83	3.00	97(9), 124(4), 180(2), 60(1), 111(1), 154(1)
113	.50	.16	111(1)
114	1.50	-	-
115	1.00	-	-
116	1.83	.50	114(2), 110(1)
117	.50	-	-
118	1.50	-	-
119	1.16	-	-
120	2.00	-	-
121	.66	-	-
122	2.00	.33	22(1), 42(1)
123	1.16	-	-
124	.83	1.16	112(7)
125	.83	-	-
126	.50	-	-
127	2.33	-	-
128	.83	-	-
129	.66	.66	2(1), 151(1), 185(1), 187(1)

Table 3 Continued

Target Number	Number of Misses	Number of Confusions	Non-Targets Confused With the Target Item
130	.16	-	-
131	-	.33	88(1), 205(1)
132	1.66	.33	121(1), 126(1)
133	1.00	1.50	148(6), 44(2), 88(1)
134	1.83	.16	18(1)
135	1.33	.16	42(1)
136	1.16	-	-
137	2.00	-	-
138	1.00	-	-
139	1.33	-	-
140	.83	.83	166(5)
141	1.16	-	-
142	1.83	.16	146(1)
143	.50	.16	108(1)
144	1.33	-	-
145	.83	.33	171(2)
146	1.00	1.00	7(1), 9(1), 10(1), 30(1), 142(1), 172(1)
147	2.16	.16	185(1)
148	2.16	.50	174(2), 95(1)
149	1.00	-	-
150	2.00	.33	15(1), 192(1)
151	2.00	1.16	197(3), 151(2), 177(2)
152	.50	-	-
153	.83	.16	118(1)
154	1.16	.16	12(1)
155	.66	.33	18(1), 181(1)
156	1.16	.50	18(1), 85(1), 120(1)
157	1.50	-	-
158	2.00	-	-
159	.66	-	-
160	1.33	-	-
161	.83	.16	182(1)
162	.83	-	-
163	1.33	.50	92(1), 189(1), 168(1)
164	1.16	.50	190(2), 189(1)
165	1.50	-	-
166	1.50	-	-
167	.66	-	-
168	.66	.33	141(1), 146(1)
169	.66	.16	143(1)
170	.66	.16	88(1)
171	1.83	.33	31(1), 154(1)
172	.50	-	-
173	1.00	-	-
174	.83	2.00	148(12)

Table 3 Continued

Target Number	Number of Misses	Number of Confusions	Non-Targets Confused With the Target Item
175	1.00	.16	149(1)
176	.66	.16	150(1)
177	1.16	.33	118(1), 147(1)
178	.16	.50	96(1), 152(1), 180(1)
179	.66	-	-
180	.33	.16	154(1)
181	.50	-	-
182	1.16	-	-
183	.83	-	-
184	1.33	-	-
185	.66	.50	159(3)
186	1.16	-	-
187	2.00	-	-
188	.83	1.83	11(1), 12(1), 19(1), 67(1), 130(1), 41(1), 48(1), 123(1), 142(1), 187(1), 204(1)
189	.33	-	-
190	.16	.33	164(2)
191	.83	.33	165(2)
192	.50	1.33	205(8)
193	.50	1.16	202(7)
194	.66	.33	203(2)
195	1.00	.33	204(2)
196	.66	1.50	132(3), 207(2), 155(1)
197	3.00	1.00	206(2), 151(2), 177(1), 95(1)
198	1.00	.33	207(2)
199	1.16	3.38	208(23)
200	1.50	2.50	209(11), 169(1), 197(1), 206(1), 210(1)
201	.16	1.33	192(7), 194(1)
202	1.50	3.50	193(19), 195(1), 188(1)
203	.50	4.00	194(24)
204	.50	-	-
205	.50	.83	192(5)
206	1.16	1.50	197(8), 200(1)
207	.50	-	-
208	.83	2.33	199(14)
209	2.16	4.50	200(27)
210	.83	1.16	51(6), 4(1)

Table 4

Symbols Suggested for Elimination Due to High Confusability
and the Associated Symbols Which Would be Aided by Their Elimination

Symbols to be Eliminated	Symbols Aided
200	209
18	27
194	203
193	202
199	208
192	201
196	205
112	97, 124
39	33, 37, 42
111	97
148	174
34	20, 42
197	151, 206
126	48
26	6
210	51
14	5
166	140

Table 5

Rank Ordering of Symbols on the Basis of Target Mean, Non-Target Median, and a Combination of These Reaction Times After the Elimination of Confusable Symbols

Target Symbol	Target Mean	Non-Target Median	Combined	Target Symbol	Target Mean	Non-Target Median	Combined
1	149	161	165	41	1	96	2
2	42	44	36	42	153	59	126
3	134	82	110	43	95	139	105
4	83	15	55	44	186	75	181
5	159	64	137	45	190	114	190
6	125	100	109	46	112	97	94
7	128	26	96	47	157	128	157
8	65	168	99	48	91	41	68
9	164	176	176	49	146	111	132
10	100	140	106	50	66	143	84
11	122	159	124	51	7	2	5
12	185	124	184	52	166	42	139
13	49	63	44	53	4	66	4
14	-	-	-	54	21	22	17
15	151	189	178	55	39	191	111
16	32	25	26	56	46	18	33
17	158	116	145	57	141	110	122
18	-	-	-	58	137	175	162
19	182	122	182	59	173	178	183
20	183	104	180	60	28	35	25
21	148	68	120	61	179	125	177
22	150	157	164	62	103	117	93
23	53	78	49	63	37	109	43
24	82	120	81	64	30	146	53
25	11	13	8	65	73	46	57
26	-	-	-	66	40	151	69
27	74	163	101	67	142	85	118
28	5	126	7	68	43	11	30
29	170	24	154	69	24	77	28
30	36	28	29	70	80	192	146
31	14	31	12	71	8	37	10
32	109	89	89	72	101	71	78
33	174	123	175	73	162	154	167
34	-	-	-	74	136	142	136
35	41	17	31	75	26	160	56
36	152	86	131	76	118	103	100
37	192	129	192	77	27	84	32
38	178	80	174	78	77	12	51
39	-	-	-	79	78	36	54
40	167	95	152	80	90	184	142

Table 5 Continued

Target Symbol	Target Mean	Non-Target Median	Combined	Target Symbol	Target Mean	Non-Target Median	Combined
81	105	150	112	121	108	181	159
82	58	156	83	122	44	27	34
83	143	130	144	123	22	58	23
84	180	177	186	124	138	171	156
85	2	19	1	125	139	119	121
86	13	99	18	126	-	-	-
87	29	98	35	127	104	172	128
88	99	102	85	128	106	47	77
89	16	76	20	129	184	132	185
90	52	34	40	130	181	91	179
91	9	1	6	131	115	74	91
92	131	92	108	132	17	20	14
93	71	88	63	133	72	4	45
94	55	180	116	134	94	45	70
95	15	29	13	135	120	94	98
96	76	40	58	136	35	107	38
97	191	39	191	137	84	164	107
98	135	173	153	138	23	53	22
99	163	112	148	139	127	162	138
100	85	187	140	140	130	115	113
101	147	134	150	141	188	70	187
102	81	106	74	142	116	165	129
103	51	149	76	143	154	138	160
104	92	23	64	144	98	169	117
105	64	188	127	145	75	182	134
106	133	49	103	146	87	21	60
107	172	54	166	147	140	148	141
108	160	158	168	148	-	-	-
109	119	137	115	149	63	7	41
110	20	3	16	150	47	83	46
111	-	-	-	151	50	33	37
112	-	-	-	152	114	81	92
113	113	118	102	153	175	87	172
114	34	6	21	154	89	79	73
115	121	170	135	155	168	50	155
116	93	8	62	156	102	51	75
117	96	90	80	157	156	121	143
118	56	69	50	158	161	16	125
119	110	48	82	159	187	127	189
120	57	67	48	160	97	185	149

Table 5 Continued

Target Symbol	Target Mean	Non-Target Median	Combined	Target Symbol	Target Mean	Non-Target Median	Combined
161	132	52	104	186	129	145	133
162	60	65	52	187	169	55	161
163	126	14	90	188	145	73	119
164	177	61	173	189	67	186	130
165	68	113	67	190	10	152	19
166	-	-	-	191	124	190	170
167	19	135	42	192	-	-	-
168	69	179	123	193	-	-	-
169	3	60	3	194	-	-	-
170	59	9	39	195	31	153	59
171	61	38	47	196	-	-	-
172	189	93	188	197	-	-	-
173	88	43	65	198	86	32	61
174	155	141	163	199	-	-	-
175	33	10	24	200	-	-	-
176	48	133	71	201	111	147	114
177	38	136	66	202	54	166	88
178	18	5	11	203	107	183	158
179	45	174	87	204	70	144	86
180	144	155	151	205	123	57	97
181	165	105	147	206	176	72	171
182	25	61	27	207	117	30	79
183	12	56	15	208	171	108	169
184	79	101	72	209	62	167	94
185	6	131	9	210	-	-	-

Figure 1. Symbols Used in Discrimination Study.

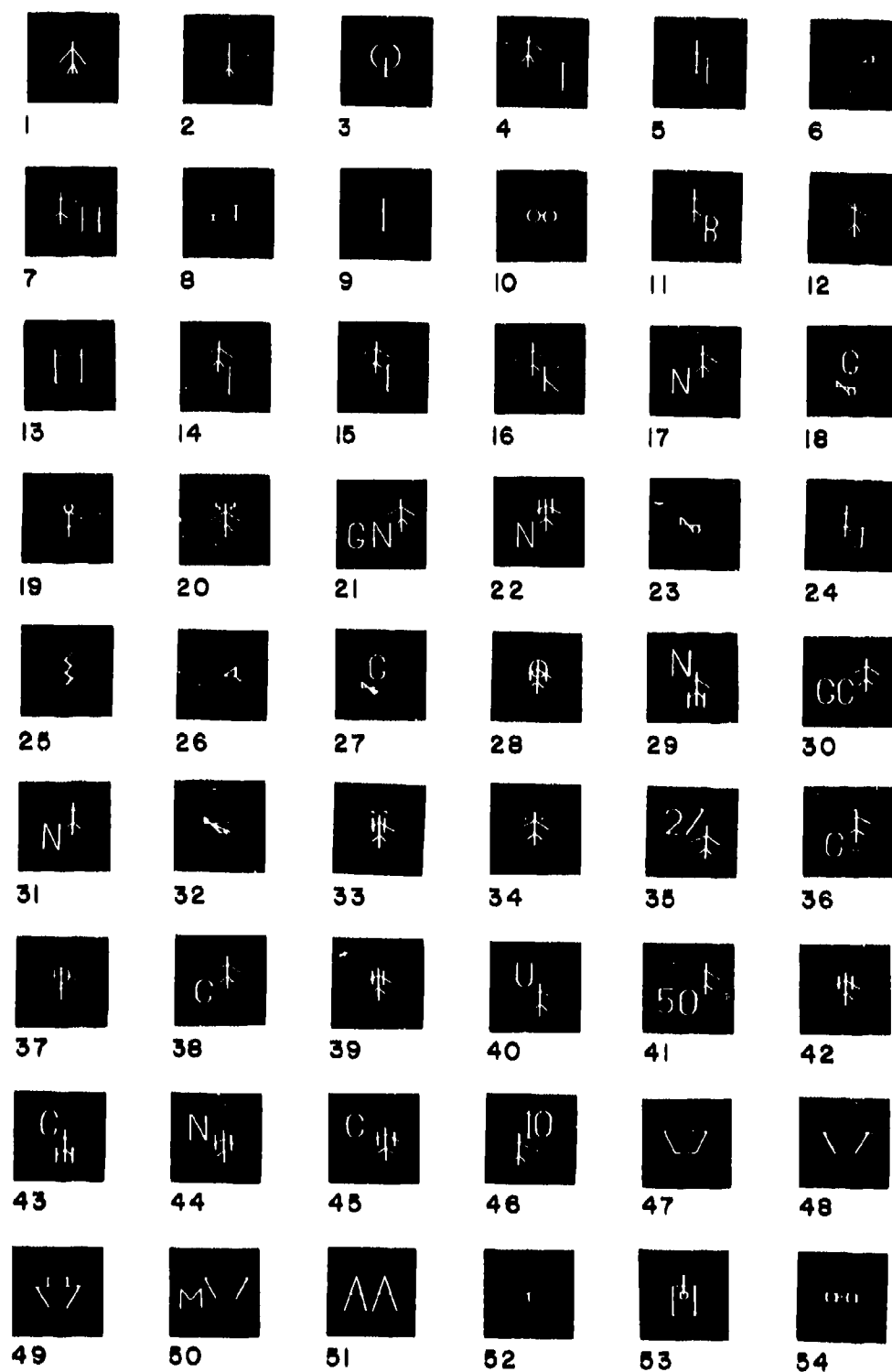


Figure 1. Continued

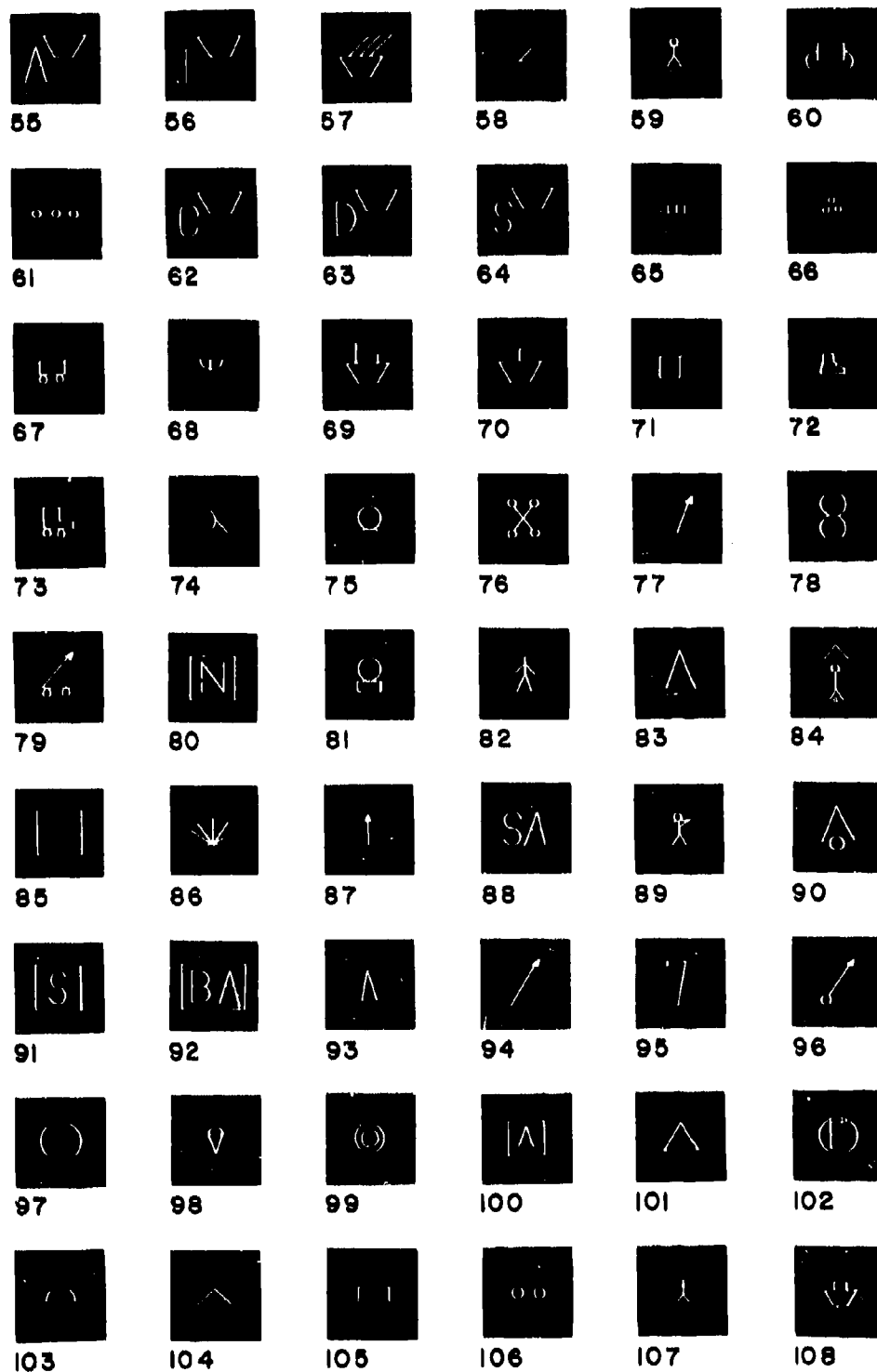


Figure 1. Continued

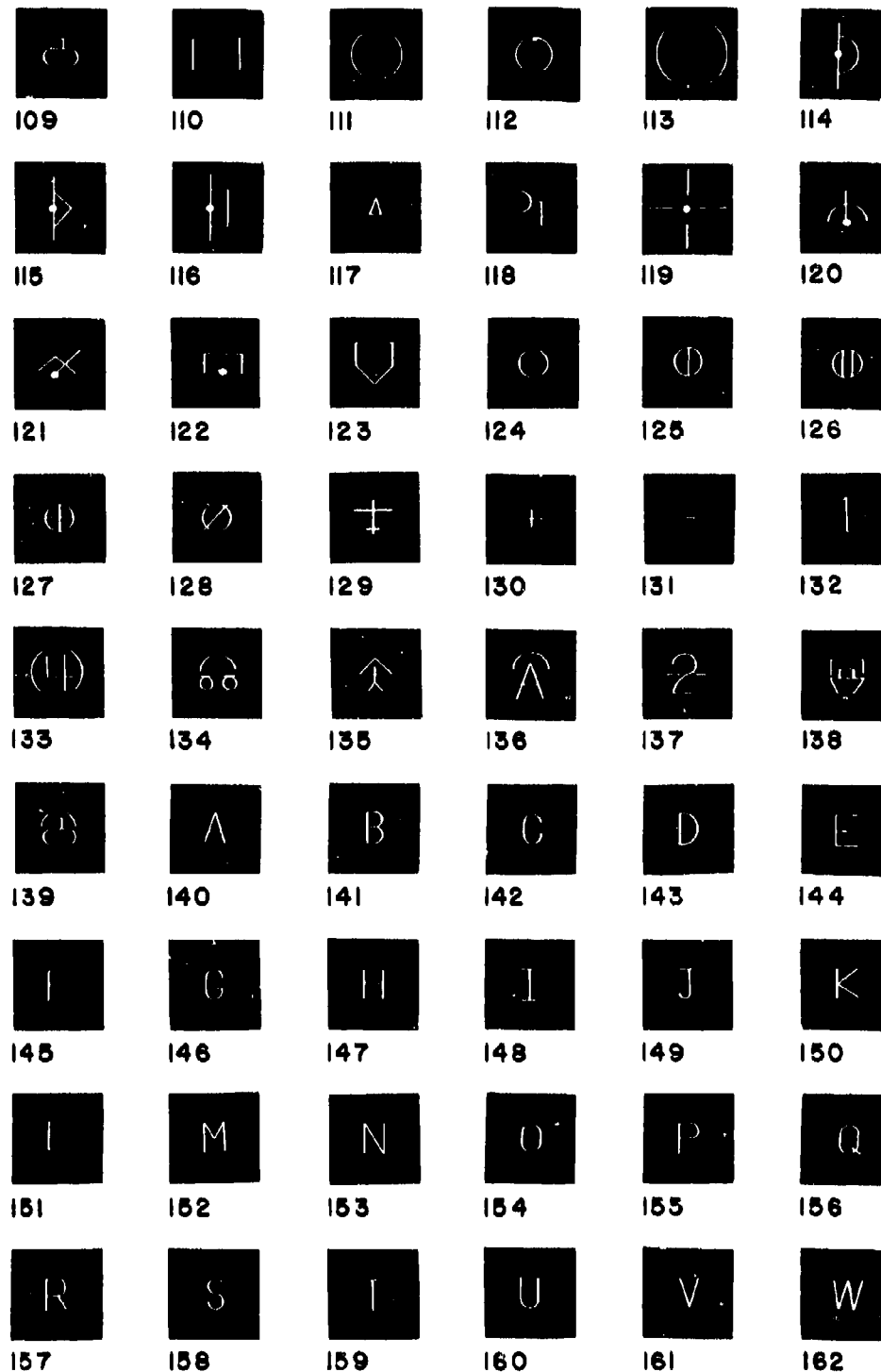


Figure 1. Continued

